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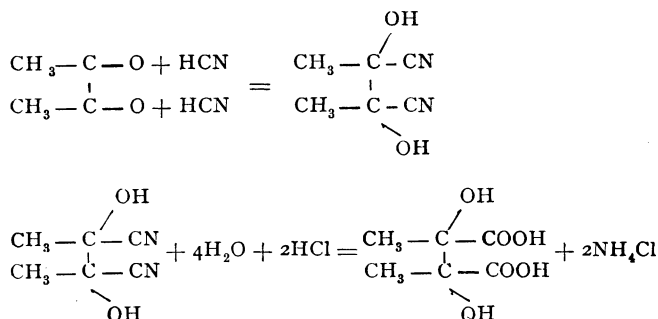
DIMETHYL RACEMIC ACID: ITS SYNTHESIS AND DERIVATIVES.

BY HARRY F. KELLER AND PHILIP MAAS.

(*Read April 7, 1904.*)

In the course of an investigation on diacetyl, the simplest diketone of the aliphatic series, Fittig¹ and one of us obtained a crystallized acid of the composition $C_6H_{10}O_6 + H_2O$, which they recognized as a dimethyl derivative of racemic acid. Continuing the work on diacetyl, we prepared the diketone on a larger scale, and it occurred to us to utilize the accumulated residues for a more extended study of dimethyl racemic acid. In view of the close relationship and the striking resemblance which this compound bears to the tartaric acids, and of certain interesting questions which had been suggested in the original research, it seemed well worth while to take up this line of work. Unfortunately the time we could devote to it has been very limited, so that the results we have to present are somewhat fragmentary, and much remains to be done.

The conversion of diacetyl into the desired acid was effected by the same process as that employed by Strecker in his well-known synthesis of racemic acid, that is by successively treating the diketone with hydrocyanic and hydrochloric acids. Thus



These reactions, consisting in the addition of hydrocyanic acid to an aldehyde or ketone, followed by "saponification" or hydrolysis of the resulting cyanhydrin, are regarded as generally applicable to aldehydes and ketones and are, of course, familiar to every

¹ Liebig's *Annalen der Chemie*, Vol. 249, p. 208.

student of organic chemistry. Nevertheless only meagre descriptions of the manner in which they have been applied in the various cases are to be found in the special literature of the subject, and no little difficulty was experienced in ascertaining the conditions favorable to the formation of the dicyanhydrin of diacetyl and its conversion into dimethyl racemic acid.

Numerous and varied were the attempts to effect a quantitative union of the diketone with hydrocyanic acid, but in no case did the yield of the dicyanhydrin exceed 30% of the theoretical. Large quantities of other products, among them the monocyanhydrin, were always formed. The method generally recommended, that of Wislicenus and Urech,¹ in which the compound containing the ketonic group, CO, is made to react with hydrocyanic acid in the nascent state, gave very poor results, and the only way in which larger quantities of the desired product could be obtained, was that originally used by Fittig and Keller.

It consists in mixing diacetyl with aqueous hydrocyanic acid. The best results were obtained by adhering to the following directions: The diketone in portions of about 20 grammes is gradually added to a 30% solution of hydrocyanic acid, the heat of the reaction being checked by cooling with water. The mixture is then placed into a pressure bottle and heated in the water bath at about 60° for some hours. The product of the reaction may now be extracted with ether (in which it is quite soluble), or it may be directly converted into dimethyl racemic acid by treating the solution with hydrochloric acid. The former seems preferable, since it facilitates the purification of the final product.

The saponification of the crystallized dicyanhydrin presents no difficulties. Recent experiments have shown that it proceeds rapidly and nearly quantitatively, when the substance is heated with ordinary hydrochloric acid *under pressure* at 100°. After removing the excess of hydrochloric acid by evaporation on the water bath, the residue, containing much ammonium chloride and some tarry matter, is dissolved in water, the solution filtered, and the filtrate carefully neutralized with baryta water. It is then boiled with further additions of baryta (to decompose the ammonium chloride), and allowed to stand after having been made slightly acid with acetic acid; barium dimethyl racemate separates as a

¹Liebig's *Annalen der Chemie*, Vol. 164, p. 255.

characteristic crystalline precipitate. Its separation may be promoted by the introduction of a few particles of the solid salt.

The free acid is readily obtained from this barium salt by means of sulphuric acid. The theoretical quantity of the latter, diluted with water, is added to the finely powdered substance, and the mixture heated with occasional stirring. When the decomposition appears complete, the barium sulphate formed is filtered off, and the filtered solution evaporated to crystallization. The dimethyl racemic acid thus prepared generally forms large transparent crystals, and is easily purified by repeated crystallizations. This process of extracting the dimethyl racemic acid from the products of the action of hydrochloric acid and diacetyl dicyanhydrin, is more convenient and gives a better yield than that described by Fittig and Keller. More than 60 grammes of material have been made by its means.

Properties of Dimethyl Racemic Acid.—The physical properties of the acid have been accurately described by its discoverers, and little can be added here to their description. Although remarkably fine crystals have been repeatedly obtained, a definite determination of their form remains to be made. There is reason, however, for believing that racemic acid is *not* isomorphous with its dimethyl derivative. Contrary also to a previous statement, it has been observed that when crystals of dimethyl racemic acid are kept for a long time they *do* effloresce, though far more slowly than those of racemic acid.

The water of crystallization is completely expelled at 105° , redeterminations of its amount gave 9.05% and 9.12%; theory requires 9.18%. Above 110° there is a further loss of weight, owing no doubt to a slow decomposition of the molecule.

The solution of dimethyl racemic acid in water, like that of other synthetic compounds containing assymetric carbon atoms, is optically inactive.

Salts of Dimethyl Racemic Acid.—With the very limited amount of acid at their disposal, Fittig and Keller were able to prepare but a small number of the salts, and three of these only were obtained in a pure state and in quantities sufficient to permit analytical determinations. The data thus secured were, however, sufficient to confirm the composition of their acid, and to establish its close analogy with the tartaric acids. At the same time certain anomalies in the composition and some of the properties of the dim-

ethyl racemates were observed, which rendered a more elaborate study of these salts desirable. This was the object in the experiments recorded on the following pages.

The neutral salts of sodium, potassium and ammonium, which are very soluble in water, were made by neutralizing weighed portions of the acid with calculated quantities of the alkaline carbonates or ammonia, and evaporating to crystallization.

Sodium dimethyl racemate, $C_6H_8O_6Na_2 + 4H_2O$, forms minute, efflorescent needles. A freshly prepared specimen yielded 23.85% of water, while two others which had been exposed to the air for some time, gave 17.65% and 16.14% respectively. Theory requires 24.48%. The amount of sodium in the anhydrous salt was—

	<i>Required.</i>	<i>Found.</i>
Na.....	20.72%	20.75%

Both the *neutral* and the highly characteristic *acid potassium salt* have been previously described. A new determination of the potassium contents of the latter gave 17.87%, instead of 18.05% required.

The “Rochelle Salt” of dimethyl racemic acid appears to have the composition $C_6H_8O_6KNa + 2H_2O$. Its preparation and analysis were attended with many difficulties. On neutralizing the acid potassium salt with sodium carbonate and carefully evaporating the solution, a homogeneous crop of crystals was obtained, but on further evaporation the liquid deposited a mixture of efflorescent prisms and wart-like aggregations of clear anhydrous crystals. An analysis of the first product yielded—

	<i>Required.</i>	<i>Found.</i>
H ₂ O.....	13.14%	12.00%
K (calculated for anhydrous compound)	16.25 “	16.12 “
Na “ “ “	9.58 “	9.49 “

Unlike the salts of the alkali metals, those of the alkaline earth and heavy metals are insoluble or nearly insoluble in water, though in a few instances they are difficult to precipitate. Many of the insoluble salts contain water of crystallization, which they tenaciously retain at high temperatures. In some cases the composition corresponds to that of the racemate, in others there are notable differences both in composition and properties.

The *calcium salt* which, owing to its great insolubility, was recommended by Fittig and Keller as the most delicate means of

recognizing the presence of dimethyl racemic acid, is at once precipitated when calcium acetate or gypsum solution is added to that of one of the soluble salts. It may be obtained in a crystalline form by dissolving it in hydrochloric acid and reprecipitating with sodium acetate. Its composition varies considerably according to the conditions under which it is formed. The water of crystallization is not completely expelled below 215° , a temperature just below incipient decomposition. The following are a few of the analyses made of this salt:

	<i>Required.</i>		<i>Found.</i>		
	1 mol. H ₂ O	1½ mol. H ₂ O	I.	II.	III.
H ₂ O.....	7.65%	11.11%	7.38%		11.39%
Ca.....	17.05 "	16.46 "	17.20 "	16.12	16.33 "

The *barium salt*, $C_6H_8O_6Ba + 2H_2O$, shows a remarkable resemblance to the corresponding racemate, from which it differs, however, in that it contains one-half molecule less of water of crystallization. This point has been established by comparative analyses of both compounds. The results were—

	<i>Racemate.</i>		<i>Dimethyl racemate.</i>		
	<i>Required.</i>	<i>Found.</i>	<i>Required.</i>	<i>Found.</i>	
H ₂ O	13.64%	13.52%	10.32%	10.12%	10.42%
Ba.....	41.40 "	41.10 "	39.25 "	39.14 "	39.16 "

Magnesium salt, $C_6H_8O_6Mg + H_2O$. A white bulky precipitate. The air-dried substance gave—

	<i>Required.</i>	<i>Found.</i>
H ₂ O.....	8.25%	7.06%
Mg.....	11.01 "	10.95 "

Manganese salt, $C_6H_8O_6Mn + \frac{1}{2}H_2O$. Forms a crystalline precipitate having a faint pink tint. The formula is derived from these results:

	<i>Calculated.</i>	<i>Found.</i>
H ₂ O.....	3.75%	3.72%
Mn.....	22.91 "	22.97 "

The *zinc salt*, $C_6H_8O_6Zn + H_2O$, is obtained as a granular, white precipitate when zinc acetate is added to an alkaline salt of dimethyl racemic acid. It is almost insoluble in water and in dilute acetic acid. Determinations of the water of crystallization

in different preparations of the salt indicate that it can crystallize with either one-half mol. or one mol. of water. One specimen yielded 3.76% and 3.55% H_2O (3.60% corresponding to $\frac{1}{2}$ mol.), while the analysis of another gave these results:

	<i>Calculated.</i>	<i>Found.</i>
H_2O	6.95 %	6.87 %
Zn.....	25.18 "	25.26 "

Several attempts to estimate the zinc electrolytically gave lower results, it being found impossible to effect a complete deposition of the metal from a cyanide solution of the salt.

Cobalt and nickel salts. A curious difference was repeatedly noticed in the way in which these compounds separated from the solutions in which they were formed. The cobalt salt is invariably precipitated in the cold, and nearly quantitatively, from the liquid, while the solution in which the nickel compound is formed remains perfectly clear for days or weeks even, until it is heated or evaporated; a precipitate or residue is then formed which is about as insoluble as the cobalt compound. Both salts deposit as crystalline crusts; the color of the cobalt salt is a fine purple, that of the nickel salt apple-green. Both contain one molecule of water of crystallization, and their compositions correspond to the formulæ $\text{C}_6\text{H}_4\text{O}_6\text{Co} + \text{H}_2\text{O}$ and $\text{C}_6\text{H}_4\text{O}_6\text{Ni} + \text{H}_2\text{O}$.

	<i>Calculated.</i>	<i>Found.</i>	
H_2O	7.11%	6.13%	and 6.74%
Co.....	23.72 "	23.09 "	23.34 "
H_2O	7.07 "	6.73 "	6.85 "
Ni.....	23.23 "	23.19 "	22.76 "

The metals were determined both as sulphates and electrolytically.

Cadmium salt. This is very similar to the zinc salt, but differs from the latter in being anhydrous. Its weight remains constant to above 160° . Its solution in potassium cyanide was electrolyzed without any difficulty, and the electrolytic determination was checked by one in which the cadmium was weighed as oxide.

	<i>Required.</i>	<i>Found.</i>	
		I.	II.
Cd	38.61 %	39.20 %	38.78 %

Lead salt, $\text{C}_6\text{H}_4\text{O}_6\text{Pb} + 2\text{H}_2\text{O}$. In the earlier part of this investigation, considerable quantities of this compound were obtained as

an intermediate product in the preparation of pure dimethyl racemic acid. Its formation and properties have been described by Fittig and Keller, who were unable, however, to spare any of their material for analysis.

A carefully prepared specimen afforded the following determinations:

	<i>Required.</i>	<i>Found.</i>
H ₂ O	8.59%	8.52%
Pb	49.40%	49.22%

The *copper salt* is anhydrous. When a solution of copper acetate is added to a soluble dimethyl racemate, the liquid remains perfectly clear, but on acidifying it with acetic acid, a light green amorphous precipitate is produced. It is probable, therefore, that this copper compound when first formed exists in the colloidal state. The weight of the air-dry salt remained constant on heating; it yielded—

	<i>Calculated.</i>	<i>Found.</i>
Cu	26.39%	26.49%

Silver salt. A voluminous and amorphous precipitate, which becomes denser on standing and darkens when exposed to light, results upon addition of silver nitrate to a neutral solution of the sodium salt. It is likewise anhydrous.

	<i>Calculated.</i>	<i>Found.</i>
Ag	55.10%	54.76% and 54.92%

When we compare the above results with the composition and properties of the corresponding tartrates, and more particularly the racemates, we are forced to admit that the acid obtained from diacetyl bears the closest resemblance to the group of isomeric compounds, of which it is the dimethyl derivative. Such differences as have been observed between dimethyl racemates and racemates are no greater (if indeed as great) than those known to exist among the salts of the several modifications of tartaric acid.

Action of Heat upon Dimethyl Racemic Acid.—It was noticed by Fittig and Keller that when the acid is heated to 178°–179° it melts with partial decomposition, and is completely volatilized, without charring, when the temperature is raised sufficiently.

Experiments, which have thus far been made on a small scale only, indicate the presence of at least one, and probably of two

acids among the volatile decomposition products. In one case a few grammes of the acid, contained in a miniature retort, were slowly heated in the paraffin bath, the volatile products being condensed in well-cooled tubes. Two distinct stages in the decomposition were observed. Just above the melting point the substance began to boil, giving off pungent-smelling vapors. The aqueous distillate had a strongly acid reaction, and on extracting it with ether and evaporating this solvent, a small quantity of needle-like crystals, having acid properties, was obtained. When the residue in the retort was heated to about 250° , renewed boiling, and more vigorous than before, took place. The distillate, which was of course separately collected, was oily and viscous, and was found to consist largely of an ether-soluble acid. It has not been prepared in sufficient quantity to permit an analysis. The ammonium salt crystallizes in little prisms, and its solution yields precipitates with calcium, barium, lead and silver salts. The lead salt deposits in beautiful stellated aggregates and seems very characteristic. The study of the decomposition products of dimethyl racemic acid will be continued as soon as enough of the starting material can be procured.

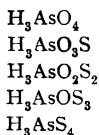
*Central High School, Philadelphia,
April 7, 1904.*

TRISULPHOXYARSENIC ACID.

BY LEROY W. MCCAY.

(*Read April 7, 1904.*)

About eighteen years ago, in order to account for the irregularities accompanying the interaction of sulphuretted hydrogen and arsenic acid, I assumed the existence of three sulphyoxyarsenic acids lying between arsenic and sulpharsenic acid:



That the monosulphyoxyarsenic acid can exist in the free state I showed in 1886. A few months later Preis, of the University of